Aviation and Global Climate Change

FOCUS ON GREENHOUSE GASSES

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For the:

National Aeronautics and Space Administration's
Office of Aerospace Technology

This report has been prepared in response to NASA Contract NASW-4967. It was prepared as a research paper for NASA by SAIC and in no way represents a NASA position or view on this subject.

Table of Contents

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I. Background:

The role of greenhouse gasses in NASA's Environmental Compatibility of Aviation (ECoA) program was a topic of discussion and concern during the ECoA workshops conducted by NASA in the Spring and Summer of 1998. This paper provides background to the participants in the ECoA Workshops regarding Global Climate Change (GCC) and the set of issues that surround it. At the time this paper was written the various agreements and issues surrounding GCC and their implications on commercial aviation had not been resolved.

Greenhouse gasses are the focus of international environmental discussions and agreements that climaxed with the 'Kyoto Protocol to the United Nations Framework Convention on Climate Change' in December 1997. A number of provisions from the Protocol were subsequently addressed in more detail at a working level meeting in Buenos Aires in November 1998. At that time the participants addressed the structure and content of the mechanisms for implementing the Protocol. While some progress was made at Buenos Aires, the participants were not able to reach closure and a number of key issues were remanded to working groups for further study.

Despite the attention being given these issues in international deliberations, the impact of the Protocol on international civilian aviation has not been determined. (Domestic flights generally will be covered under each country's emissions budget.) The provisions of the Kyoto Protocol specify that the measures governing emissions of greenhouse gasses (greenhouse gasses) for international civilian aviation will be addressed by the International Civil Aviation Organization (ICAO). While ICAO has held meetings to discuss these issues, no provisions specific to the Protocol have been agreed to at this time.

This study will attempt to be comprehensive in terms of its scope, strategic in its outlook, and relevant to the concerns of aviation vis-à-vis this set of issues. The paper provides general information on the global contributions of various regions of the world as well as types of activities (commercial, transportation, manufacturing, etc.) to help the reader put the overall problem in perspective and to understand the relative role of aviation**.** A broad overview of research and technology development programs to address these problems will be included. Finally the paper will discuss and analyze proposed strategies and policies for dealing with the greenhouse gas issues.

II. Discussion:

Greenhouse Gas[1] Phenomena

Greenhouse effect refers to a physical property of the Earth's atmosphere. If there were no greenhouse gasses in the earth's atmosphere, the earth's average temperature would be near zero degrees Fahrenheit; however, the average temperature is nearly 60º warmer. This difference in temperature is attributable to the presence in the atmosphere of Water (H2O) in vapor form, Carbon Dioxide (CO2), Ozone (O3) and a number of other gasses that have similar properties. In its natural state our atmospheric system balances

[1] Greenhouse gasses refer to a suite of gasses in the Earth's atmosphere system that balance absorption of solar radiation by emission of infrared radiation to space. The atmosphere absorbs more infrared energy than it reradiates to space, resulting in a net warming of the Earth's atmosphere system and surface temperature. Primer on Greenhouse Gases, Wuebbles and Edmonds, Lewis Publishers, 1991.

the absorption of solar radiation by emission of infrared radiation into space. The atmosphere absorbs more infrared energy than it radiates. This results in a net warming of the atmosphere and an increase in the surface temperature.

The concern about human-induced change in climate grows out of the relatively recent increase in the atmospheric levels of greenhouse gasses. There is direct evidence that the increasing use of fossil fuels (oil, natural gas, and coal) in the past 150 years has been the primary cause of the increasing levels of greenhouse gasses. The principal manmade gasses of concern include CO2, Nitrogen Oxides (NOx), Methane (CH4)[2] and a series of fluorocarbons (HFCs, PFCs, and SF6).[3] CO2 accounts for roughly half of the greenhouse effect; all other greenhouse gasses account for the other half. Therefore, it is not unexpected that CO2 receives most of the attention in the literature and in the discussions of remedies. A very high percentage of man-made CO2 is generated in the burning of fossil fuels. The production and use of fossil fuels also generates a considerable portion of the NOx and Methane that is related to human activities. Therefore, much of the focus of the proposed remedial actions is also aimed at these same fossil fuels.

Unlike some emissions (such as sulfur oxides) most greenhouse gasses tend to disperse relatively evenly throughout the atmosphere[4] due to their long residence time in the atmosphere. This is of central importance in devising a remedy, in that, emissions in any part of the world will contribute to the overall global greenhouse effect. Thus actions by an individual nation or a small group of nations will have limited impact on the overall condition. This necessitates a global approach to resolving the problem and requires that most countries participate.

All greenhouse gasses are not created equal. Nearly all of these gasses have a different "strength" (that is, the capacity to trap and retain infrared radiation and prevent that heat from escaping the earth's atmosphere). Table 1 shows that potency for molecules of different gasses in terms of the relative strength of CO2. Some man-made gasses have the capability to capture thousands of times more heat than CO2 per molecule. Thus even though there maybe a much smaller volume of such gasses their role vis-à-vis global warming may be important. Most of the gasses of concern have long average lifetimes (e.g., the average lifetime of CO2 is estimated to be between 120 and 150 years.). The table below shows the relative lifetime of four key greenhouse gasses. It also provides a comparison of the relative effect a molecule of each of these gasses has in relation to the effect of one molecule of CO2.

Table 1
Comparison of Greenhouse Gasses[5]

Greenhouse Gas	Average Life (yrs.)	Radiative Value vis-a-vis CO2
CO2	~120 – 250	1
CH4	~10	21
NO2	~130	206
CFCl3 (CFC11)	~65	12,400

[2] Nitrogen oxides are primarily in the form of NO2; this is a byproduct of high temperature combustion. Methane is a hydrocarbon fuel more commonly called natural gas. Man made releases of methane often occur in the production, transportation or use of natural gas. (Methane is also generated and maybe released to the atmosphere in natural processes involving the decay of plant or animal matter.)

[3] HFCs are a substitute for CFCs that were banned by the Montreal Protocol and are primarily used for refrigeration; PFCs are a byproduct of aluminum smelting and uranium enriching; and SF6 is used as an insulator in electrical transmission systems.

[4] One greenhouse gas that does not disperse evenly is water vapor. Water vapor in the atmosphere is primarily a function of natural processes. One exception relative to aviation and the environment is the water vapor from aircraft that is emitted into the upper troposphere and the lower stratosphere.

[5] Source for relative values Primer on Greenhouse Gases, Wuebbles and Edmonds. There are varying estimates of the average life of CO2 in the atmosphere; these numbers represent the range of reasonable estimates.

Prior to the onset of the industrial age, the overall atmospheric system of various gasses is believed to have been in relative balance for thousands of years. Human activities associated with industrialization and the growth in world population have disturbed that balance as evidenced by the increasing levels of CO2 and other greenhouse gasses. The levels of man made CO2, NOx and methane are small compared to the overall flows that occur naturally[6] (gasses emitted and gasses taken up by natural processes), nevertheless, over time these small increments have a cumulative effect on the overall levels of greenhouse gasses present in the atmosphere. Because of the long average life of these gasses, any additional CO2 (as well as some of the other greenhouse gasses) produced by man can be expected to remain in the atmosphere for more than one hundred years.

Overview of Greenhouse Gasses

Table 2 provides some general data on global emissions of CO2 by Country and Region based on 1996 data. The United States is the largest emitter of CO2; however, emissions from China are more than half of that level. The high level of emissions from China has caused concern among those who insist that Developing Countries must be included in any agreements to control global emissions.

Table 2
Carbon Emissions by Country/Region for 1996[7]
(As a percent of World Emissions)

Country or Region	Percentage
China	13
United States	24
FSU & East Europe	14
Western Europe	16
Other	17
Other Far East	16

In absolute terms, during the 10-year period, 1986 through 1995, global emissions of CO2 have increased by nearly 18 % from 4,666 to 5,484 million tons per year. For 1998 global emissions are estimated to be approximately 6,000 million tons.

For the United States, 1990 carbon emissions were estimated at 1346 million tons. The forecast in the Energy Information Agency[8] Reference Case for the year 2000 is projected to be 1585 million tons, which is 18 percent higher than the 1990 level. For 2010 (which is the mid-point for the Kyoto agreement) the estimate is for 1670 or 24 percent above the 1990 level. This is forecast to increase to 1,975 million tons by the year 2020 in the Reference Case, roughly 33 percent above the 1990 levels.[9] The Reference Case is based on the assumption that only voluntary actions (as set forth by the 1992 Rio Treaty) would be undertaken. It does not consider the impact of mandatory actions that might result from

[6] Each year more than 10% of the total atmospheric carbon dioxide is reduced to carbohydrates by photosynthetic organisms. Most, if not all, of the reduced carbon is returned to the atmosphere as carbon dioxide by microbial, plant and animal metabolism, and by biomass combustion.
[7] Energy Information Agency, Department of Energy.
[8] The Energy Information Agency prepares forecasts of emissions for CO2 and other greenhouse gasses since energy production and use accounts for more than 80 per cent of human originated greenhouse gasses.
[9] From the Annual Energy Forecast of the Energy Information Agency and are based on mid-year forecasts by their National Energy Modeling System. There are two other cases presented by EIA, which bound the range of forecasts, these cases include various assumptions about economic growth, fuel switching, energy conservation, deployment of new technology and carbon prices.

the Kyoto Protocol. (The Rio Treaty and the Kyoto Protocol will be discussed in more detail in a later section.)
Much of the analysis of greenhouse gasses for the United States has focussed on energy. This is understandable since more than 80 percent of the greenhouse gas emissions are related to energy production and use. Table 3 below provides an overview of our energy system in terms of the types of fuel used and the sectors of our economy that use that energy.

Table 3
Energy Use in the United States
Fuel Type and Using Sector
As a percent of Total for 1997

Fuel Type	Percent	End Use	Percent
Petroleum	38.5	Transportation	26.3
Natural Gas	23.9	Industrial	37.9
Coal	22.8	Residential/Commercial	35.8
Nuclear	7.0		
Other[10]	7.8	Total End Use	100.0%
Total Fuel	100.0%		

Note: Electric Conversion Losses are equal to 22.7% of Fuel Used.[11]

Most of the coal used in the United States goes to generate electricity. More than half of the electricity generated in the United States is produced from coal. Nuclear energy is used exclusively for producing electric power; and a significant part of energy from other sources also goes into the production of electricity. On the other hand, transportation relies almost entirely on petroleum derived fuels (97%). The residential and commercial sector relies on electrical power and natural gas for most of its energy needs. The industrial sector uses natural gas, petroleum and electricity.

III. Scientific Perspectives:

One cannot read any general discussion of global climate change without hearing at least one challenge to the scientific validity of some part of the argument. As with any number of complex natural systems, there are many unknowns regarding the physical phenomena at work in determining climate, especially global changes in climate. This section will start with a discussion of several points of scientific consensus and then proceed to those areas where there are differences of scientific opinion.

Points of Scientific Agreement:

Atmospheric levels of greenhouse gasses are increasing. There is clear scientific evidence that the levels of CO2 in the atmosphere are increasing. The levels of CO2 have increased from 280 ppmv before the industrial revolution to 360 ppmv by 1995. Furthermore, this evidence shows that the rate of increase is increasing. Most of the increase in CO2 since the mid-1800s has occurred recently. Nearly half of this

[10] Other includes hydropower, geothermal and a number of renewable energy forms (wood, wind, solar, etc.).
[11] Electrical energy conversion is an intermediate step whereby one energy form is converted into another more useful form. It is not an end use in the normal meaning of the term. In this conversion process energy losses are incurred. Electrical energy is generated primarily from fossil fuels and nuclear power, however, it is used for industrial, residential and commercial purposes. Very little electricity is used for transportation.

increase has occurred in the last three decades.[12] There is likewise clear evidence that many other greenhouse gasses are also increasing. These facts have been documented by the scientific community and are not in dispute.

In addition to the measurements of such gasses in the atmosphere, there is also agreement among the scientific community as to the cause of this increase. There is agreement that the increase of greenhouse gasses has an anthropogenic origin, that is, it is closely related to man's activities. The levels of CO2 that began to rise not long after the beginning of the industrial revolution continue to rise today and the annual amount of the increase continues to rise. These are primarily attributed to the increasing use of fossil fuels, although deforestation associated with land use and agriculture and have also been contributors.

Diverging Opinions:

There is another class of scientific findings and conclusions that are generally accepted by much of the scientific community. Proxy measurements using core samples from glaciers, ice fields and sea bottoms have provided a record of CO2 in the atmosphere going back hundreds of thousands of years. Accompanying evidence supports the contention that periods in which there were high levels of carbon dioxide in the atmosphere correlate with related evidence of higher temperatures. The coincidence of these events is generally accepted, however, the cause and effect relationships are sometimes debated.

The conventional wisdom as to the general implications of the increases in greenhouse gasses is accepted by most of the scientific community. These are regarded as logical outcomes of the behavior of such gasses and the logical extension is accepted that increased levels of such gasses should affect the temperature and thereby the climate. Beyond general agreement as to the direction of that change, that is, global temperatures will increase; scientific opinion begins to diverge. Forecasts and projections as to the speed and intensity of climate change and its specific manifestations vary considerably among scientists. This is particularly evident as one moves toward forecasts of specific impacts in specific regions. Professor Eric Barron of the Earth System Science Center at The Pennsylvania State University in testimony before the Senate noted, "The best scientific assessments available suggests that the impacts of these changes will be significant, yet the error bars, or uncertainties are also very large."[13] Because the rate of atmospheric carbon dioxide increase over the last two decades has been unprecedented, many scientists are concerned that the rapidity of the buildup and the associated warming effects could exceed the ability of biological systems to adapt. This could occur even with the presumed assistance and management of the process by humans.[14]

For example, there are on going debates in the scientific and political communities as to whether or not the recent record setting high temperatures are evidence of the on set of global climate change. In good measure the arguments revolve around the difference between weather phenomena and evidence of climate change. [Unusual weather events have occurred frequently. Every year a number of record high temperatures and record low temperatures are recorded by weather stations in various parts of the world. How many record high temperatures must be recorded in a given number of consecutive years (as opposed to record setting lows) to provide ample evidence of climate change? This writer believes that climate change will only be universally acknowledged after it has become well established. At that time unusual events of several decades past will have become part of the expected weather pattern.]

[12] From the Intergovernmental Panel on Climate Change (IPCC) Second Assessment Synthesis of Scientific-Technical Information….. The report also notes that CH4 increased from 700 to 1720ppbv and NO2 from about 275 to 310ppbv during the same time period.
[13] From testimony before the Senate Committee on Environment and Public Works, July 10, 1997.
[14] From Transportation and Global Climate Change, Greene and Santini, editors, Editors Foreword.

Differences Regarding Specific Impacts:

Given the global nature of climate change attributed to greenhouse gasses, models are used extensively by scientists and other experts as a method of predicting the impacts. The theories, logic, sophistication, and levels of detail vary considerably from model to model. Therefore, it should be no surprise that the predictions and forecasts of the characteristics, speed and intensity of the impact of global climate change also vary.

There are some impacts that many models predict. For example, higher temperatures are expected to bring more adverse changes in weather patterns. Predictions call for more extended droughts, floods, and violent storms. Higher temperatures will lead to a more energetic hydrological cycle that is expected to fuel violent storms. Likewise, the occurrence of severe droughts in other parts of the world is predicated on higher rates of evaporation of moisture in the soil. Aside from these basic directional relationships, the reliability of models beyond the boundaries of empirical knowledge is called into question. It becomes more likely that actual events will include non-linear reactions and unanticipated and perhaps rapid changes.

Recent storms in the United States and the Caribbean are interpreted by some as confirmation of the theories incorporated in their models. The number and intensity of these occurrences are seen as early signs of what we can expect to occur with increasing frequency. Others, not convinced by these events, contend that these weather phenomena have always occurred and they are not unusual. They site the dust bowl situation of the 1930's and the hurricanes that ripped the Eastern United States in the 1950's as examples. Again, we are forced to differentiate between weather phenomena and climate change.

Another phenomenon that is predicted by many models is the expected rise in ocean levels as a result of thermal expansion and melting ice. Atmospheric warming is expected to have an effect on ocean temperature (although with a considerable lag time). Warming of the oceans is expected to cause an increase in the volume of sea water (as a result of thermal expansion). In addition, melting of glaciers and icecaps (Greenland and Antarctica) is expected to add to the rising sea level phenomena. Estimates of the rise in sea level that can be expected by the year 2100 vary from less than one foot to more than 3 feet.[15]

There are some measurements that indicate a small rise in sea level has occurred in the past century.[16] Likewise, receding glaciers and sea ice also have been measured in many places in the world. However, as other scientists have pointed out, scientific evidence indicates that glaciers and sea ice have often advanced and retreated over the earth's geologic history. The question remains--can the rise in sea level and the recent retreat in glaciers be attributed to global warming? The Intergovernmental Panel on Climate Change (IPCC) Second Assessment while noting the consistent global changes in climate or weather extremes that have occurred in the 20th century concluded, "…to date it has not been possible to firmly establish a clear connection between these regional changes and human activities."

The consequence of climate change has concerned many biologists, dendrologists and agronomists. A rapid change in the climate may have adverse effects on some flora and fauna. There are a sizeable number of environmental scientists who fear that many plants and animals will not be able to migrate or adapt to global warming. There is limited hard scientific information in this area and the hypotheses are speculative. Nevertheless they raise a red flag and identify a potential area of considerable concern. In

[15] The role of oceans is one of the more important uncertainties in assessing global climate change. Through photosynthesis microscopic ocean plants (phytoplankton) remove carbon dioxide from the atmosphere. As these plants die, the carbon they have absorbed is either taken up by other marine life or deposited on the ocean floor where it is eventually locked-up in sedimentary rock. The unanswered question is –will increases in CO2 in the atmosphere lead to increases in the levels of phytosynthesis by these microscopic ocean plants? Research is underway to attempt to resolve this question.

[16] IPCC Second Assessment states that global sea level has risen by between 10 and 25 cm over the past 100 years.

part the uncertainty in the assessments of these experts is attributable to the differing estimates by climate experts as to the speed and nature of the impacts of global climate change. There is a lack of agreement regarding the timing, magnitude and areas impacted by global warming.

While we know much about the global climate and greenhouse gasses, there remains much about the role of greenhouse gasses that we do not fully understand. A recent World Bank Report wrestling with the lack of certainty surrounding global warming commented,

> Although the physical processes of greenhouse warming are increasingly well understood, the degree of warming arising from increases in atmospheric concentrations of carbon dioxide cannot be measured directly, and only broad ranges can be estimated through modeling. It is even possible to question whether it is more efficient to adapt to climate change rather than to prevent it.[17]

There are also major differences among the experts and model builders regarding the treatment of a number of other natural phenomena. For example, what is the role of clouds? Are additional clouds likely to have a net cooling or warming effect?[18] How will plants and trees respond to the increases in CO2 in the atmosphere? Will they increase their level of carbon up-take? Will warmer temperatures extend the growing seasons and lead to significant plant growth and the absorption of more CO2? How should oceans be accounted for in considering models for global climate change? Will oceans increase the up take of CO2 through increased growth in phytoplankton and thereby into the ocean's food chain?

The uncertainty reflects the complexity of systems governing the carbon cycle, hydrological cycle, and biological cycles and their impact and response to increases in greenhouse gasses and likely increases in temperature. There is considerable public and private research underway as we attempt to understand these phenomena.

Research Efforts:

Scientists are finding more and more subtle interrelationships among the factors that control our climate. The report of the U. S. Global Climate Research Program summarizing their findings on changes in the polar region noted that "climate changes in the Arctic polar region could affect ocean salinity by changing the amount of fresh water runoff. This salinity plays an important role in determining the intensity of the deep ocean circulation…."[19] Such findings along with the use of super computers have made significant improvements in atmospheric and oceanic circulation models. As the spatial resolution of these models increase the need for better descriptions of clouds and ocean processes increases. In the report to congress the United States Global Climate Research Program discussed its findings from these improved climate models. They noted,

> "Climate variations on time scales of years to decades are largely controlled by how the ocean stores and transports heat from the warm regions near the equator to the colder regions at higher latitudes. Weather patterns change in response to changes in sea-surface temperatures, resulting in climate oscillations ranging from El Nino events to smaller but longer-term interdecadal variations.[20]

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[17] Monitoring Environmental Progress, World Bank, electronic publication.

[18] Transportation and Global Climate Change, Greene and Santini, Editors, from an Article by Michael Walsh. For aviation the question of clouds is important. Vapor trails by most commercial jet aircraft are deposited in the upper troposphere and lower stratosphere. The conventional wisdom is that these probably add to the global warming effect to a limited degree, however, some scientists hold the opposing view. Studies of the potential effects of these trails are on going.

[19] Our Changing Planet: The FY 1999 U. S. Global Climate Change Research Program Report to Congress. The USGCRP was created by the Global Change Research Act of 1990. It is required to prepare scientific assessments of global change and submit such assessments to the congress annually. Oversight of the program is performed by the National Science and Technology Council and the Office and Science and Technology Policy.

[20] Ibid.

The U. S. Climate Change Research Program funds a variety of projects in a number of government agencies. NASA's Earth Sciences Enterprise Project is undertaking research to observe, monitor and assess large-scale environmental processes related to climate change. The NASA effort is aimed at scientific data collection using satellites and other airborne vehicles for studying atmospheric ozone, ocean surface winds, tropical precipitation, and the Earth's upper atmosphere. In one such effort satellites are being used to measure ocean color to determine changes in marine life including microscopic marine plants. The ocean color provides a measure of biological activity at the surface and helps scientists to understand phytoplankton assimilation of carbon dioxide.[21]

The data gathered from such programs leads to related questions, such as, are there measures that can be taken to stimulate the growth of phytoplankton and thereby remove more carbon dioxide from the atmosphere? Scientists believe that the performance of photosynthetic organisms depends on the earth's atmosphere and climate. Over the next century, the large increase in the amount of atmospheric carbon dioxide from human activities is certain to have an impact on the performance and competition of photosynthetic organisms. Scientific investigation is underway to more fully understand these relationships and predict the impact of the increased levels of CO2 and the implications.[22]

NOAA has proposed a multi-step program to understand, predict and prepare for climate change. This would entail gathering basic information and data related to global observations of the climate system and inventories of greenhouse gasses.

About a dozen agencies conduct data collection, analysis and scientific investigation under the program's annual budget of nearly 2 billion dollars. Much of the knowledge gained in understanding the processes that cause climate change will eventually find its way into predictive models to aid our understanding of the effects of human activities on climate. (See Appendix A for agency funding levels for the United States Global Climate Research Program.)

Perhaps the most important questions that scientists need to answer are-- Are there built in correcting factors (negative forces) that will keep the earth in a relative state of balance? Or conversely, are there reinforcing factors (positive forces) that will cause the climate system to spiral out of control? And, perhaps, which set of these forces will dominate?

Winners and Losers:

There are a number of similar outcomes predicted by most models. If these models are correct in their forecasts of the anticipated impacts, then there will be both "winners" and "losers". For example, patterns of precipitation are expected to change in many areas of the world as a result of climate change. Some regions currently receiving rainfall adequate to meet their needs for drinking water and agriculture may find that future rainfall will be inadequate to support their needs. Conversely, other areas that have been relatively dry could see significant increases in rainfall, adequate to support increases in agriculture and a growing population. Similarly warmer temperatures may have the effect of lengthening the growing season in higher latitudes.

Many models predict that Canada and Russia could benefit from climate change. Milder winters and the prospect for increased rainfall could result in significant increases in agricultural output. Conversely parts of the Southern Plains in the United States could become unsuitable for the staple crops that are currently

[21] This is part of the SeaWiFS Project; information can be obtained from the project web site http://seawifs.gsfc.nasa.gov/
[22] John Whitmarsh, USDA and Govindjee, of the University of Illinois, "The Photosynthetic Process."

produced due to increased temperature and higher rates of evaporation. These kinds of effects can lead to winners and losers, and can dramatically change the socio-economic fortunes of a number of nations.

The timing of the adverse impacts is a matter of scientific and political debate. Will these kinds of changes occur in the near future? Or will they gradually occur over a hundred or more years? There is no certainty, and thus the urgency of the problem is also debated. This leads to procrastination by those who face difficult and unpopular political choices. Such decisions begin to turn on the question of who stands to win or lose? And, when will this occur?

Implications of Scientific Uncertainty and Conflicting Opinion:

The lack of incontrovertible scientific proof, particularly regarding the impacts of increased levels of greenhouse gasses, has made the politics of global climate change as complex as the technical aspects. The interaction between the gaps in scientific knowledge and the political arguments are readily demonstrated. In a debate over global climate change, Congressman John Dingell (D, Mi.) summed up the reservations of many skeptics when he commented on the recent IPCC report. He noted that the report stated, "…our ability to quantify the human influence on global climate is currently limited because the expected signal is still emerging from the noise of natural variability, and because there are uncertainties in key factors." He went on to provide his interpretation of this statement, "…we don't know with any degree of precision how big the problem is, and we don't know how fast it is moving. Or, indeed, how it can be mitigated."[23] He concluded that given these uncertainties the Administration should not have rushed into agreeing to many of the provisions of the Kyoto Protocol that could cause serious harm to our economy.

Perhaps an appropriate way to put our scientific understanding of global climate change into perspective can be found in the work of two planetary scientists. They have spent their careers studying the destruction of organic compounds on Mars and the destruction of clement conditions on Venus; in a recent paper they pondered what message their assessments of Mars and Venus, our two sister planets, have for Earth.[24]

> Fortunately, Earth's climate has not experienced quite the same extremes in the geologically recent past [as Venus]. Although it is also affected by volcanism, the oxygen-rich atmosphere, provided by biota and plentiful water, readily removes sulfur gases. Therefore, water clouds are key to the planet's heat balance. The amount of water vapor available to these clouds is determined by the evaporation of the oceans, which in turn depends on surface temperature. A slightly enhanced greenhouse effect on Earth puts more water into the atmosphere and results in more cloud cover. The higher reflectivity reduces the incoming solar energy and hence the temperature. This negative feedback acts as a thermostat, keeping the surface temperature moderate over short intervals (days or years). …[Other forces] also stabilize the abundance of atmospheric carbon dioxide. [These forces are] governed by the slow process of plate tectonics, this mechanism operates over time scales of about half a million years.
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> These remarkable cycles, intertwined with water and life, have saved Earth's climate from the wild excursions its sister planet has endured. Anthropogenic influences, however, operate on intermediate time-scales. The abundance of carbon dioxide in Earth's atmosphere has risen by a quarter since 1860. Although nearly all researchers agree that global warming is occurring, debate continues on how much of it is caused by the burning of fossil fuel and how much stems from natural variations. Whether there is a

[23] USIA Electronic Journal, April 1997; "The debate over Administration Policy," statement by John Dingell, senior member of the House of Representatives' Commerce Committee in a debate with Timothy Wirth, Under Secretary of State for Global Affairs.

[24] Mark Bullock and David Grinspoon, "Global Climate Change on Venus", Scientific American, March 1999. Both are from the University of Colorado. Grinspoon is a member of the Solar System Exploration Subcommittee, which advises NASA on space policy.

critical amount of carbon dioxide that overwhelms Earth's climate regulation cycles is not known. But one thing is certain: the climates of Earth-like planets can undergo abrupt transitions because of interactions among planetary-scale processes.

IV. International Actions:

Because greenhouse gasses disperse more or less uniformly around the world, global solutions are necessary if emissions of such gasses are to be controlled. Accordingly the United Nations has become the venue for pursuing political solutions among nations. As early as 1987 the United Nations began to take steps to address the problem. Since then there have been a series of measures taken in an effort to reduce emissions of greenhouse gasses.

Early efforts to reach accord began with the Montreal Protocol, an agreement to limit the production of substances that deplete the ozone layer. The Protocol was adopted in September 1987 to protect the ozone layer from destruction by chlorofluorocarbons (CFCs). The protocol established legally binding mandatory targets for developed nations limiting the production of CFCs. While not specifically addressing CFCs as greenhouse gasses, the significance of the Montreal Protocol was that it was the first time legally binding targets for nations were adopted to address a broad environmental concern of this type.

By 1990 it became clear that unless developing nations also signed the Montreal Protocol, the use of ozone-depleting substances could not be effectively reduced. That same year, Amendments to the Protocol provided for the establishment of the Multilateral Fund. The purpose of the Fund was to provide incentives for Developing Countries to eliminate the production of ozone depleting gasses. The Developed Countries contributed to this fund to assist Developing Countries in their efforts to eliminate such substances. The establishment of the fund encouraged many Developing Countries to agree to the Montreal Agreement, and by May 1997, 110 Developing Countries had committed to implementing the Protocol. Mohamed El-Ashry, CEO and Chairman of the Global Environment Facility, in commenting on the importance of the fund to Developing Country participation noted,

"…in 1987 most large Developing Countries declined to participate. Three years later, the so-called Montreal Protocol was amended to create a multilateral fund to reimburse Developing Countries for the added costs of phasing out these chemicals. Since that time, China, India and other nations have ratified the Protocol. And, with assistance from the fund, they have made significant progress toward eliminating ozone-threatening chemicals. [In his opinion] Most developing countries consider alleviating poverty and improving the living standard as their number-one challenge. Consequently, they assign primary responsibility for reducing greenhouse gasses to the developed world.[25]

The Fund is administered by four implementing agencies, they are the World Bank, the United Nations Development Program (UNDP), the United Nations Environmental Program (UNEP), and the United Nations Industrial Development Organization (UNIDO).

Preparation for Kyoto:

In 1988 The Intergovernmental Panel on Climate Change (IPCC) was created. This was the first UN sponsored organization of note to be formed for the purpose of developing potential agreements for the reduction of greenhouse gasses. The IPCC grew out of a meeting of The World Meteorological Organization and the UNEP. These organizations had met to discuss global climate change. As a result of that meeting the IPCC was created to provide leadership in addressing the scientific, technical, and

[25] Article in the Washington Post Issue Forum, November 2, 1998, "Sustainable Energy Development: A Worldwide Priority.

socio-economic issues related to global climate change. The IPCC is composed of scientists, technical advisors and other experts in the social and economic aspects of climate change. (Subsequently, the IPCC would be called upon to play an important role in the Kyoto Protocol. It was designated to provide technical and scientific advice and economic and social assessments to the Conference of the Parties, which is one of the principal working groups of the Protocol Convention.)

In 1992 "The Framework Convention on Climate Change"[26] met in Rio de Janeiro; representatives from 160 countries were in attendance to discuss global climate change. At the conclusion of the Framework Convention the participating countries adopted a "legally non-binding, voluntary pledge" that the industrialized/developed nations would reduce their greenhouse gas emissions to 1990 levels by the year 2000. The "Voluntary Action Plan" was ratified by the United States in 1993. Unfortunately, this plan failed to generate any major concrete actions on the part of the United States or Japan and as a result did not make serious inroads to reduce CO2.[27]

By 1995 it became apparent that major CO2 contributing countries would not meet their targets; therefore, the parties to the treaty agreed to enter into negotiations to establish legally binding limits for the reduction of greenhouse gasses. This led directly to the steps that would culminate in the Kyoto Protocol. (On a less positive note, by including only the industrialized nations the Rio Convention set a precedent that would become a key issue at subsequent meetings, namely, the exclusion of the Developing Countries from the greenhouse gas reductions. This is one of the major points of contention in the U. S. Congress on both the Rio Convention and subsequently with the Kyoto Protocol.)

As an interesting footnote on the failure of the United States to respond to the voluntary plan was the November 1998 report by the Energy Information Administration on U. S. emissions of greenhouse gasses. The report noted that emissions for 1997 increased over 1996, however the growth rate was down substantially from 1996.

"The EIA found that emissions of carbon dioxide increased by 1.5 percent while the growth in U. S. emissions of other greenhouse gasses was relatively flat in 1997. Although greenhouse gas emissions grew less rapidly than the U. S. economy, they grew at a rate slightly higher than population growth. For the first time in six years, hardly any of the growth was attributable to transportation, the EIA found."[28]

The 1997 data raises questions about the voluntary program; namely, did we wait long enough before moving toward a mandatory targeting approach? Or were 1997 emissions levels simply an anomaly?

V. The Kyoto Protocol

Following several preliminary meetings, in December of 1997 some 160 nations met in Kyoto, Japan.[29] The purpose of the Kyoto meeting was to create a protocol agreement that would begin the process of

[26] The Framework Convention was held in Rio de Janeiro in conjunction with The Earth Summit. The Framework Convention on Climate Change, or "Rio Treaty," was signed by more than 160 countries on May 4, 1992. In April 1993 the President committed the United States to stabilize greenhouse gasses emissions by 2000 at 1990 levels. The Energy Policy Act of 1992 contained several provisions for voluntary reductions including reporting of emission gasses.

[27] Testimony by Professor D. W. Jorgenson, Harvard University, before the Senate Committee on Environment and Public Works, July 17, 1997.

[28] Washington Post, November 1, 1998, "Greenhouse Gases' Increase Slows."

[29] Calendar of Major events surrounding the Framework Convention on Climate Change:
1992—May--Adoption of U. N. Framework Convention on Climate Change (NY);
June—Convention signed in Rio de Janeiro, Brazil;
October—Convention ratified by the U. S. (Convention entered into force in March of 1994.)
1995—March-April—First Conference of the Parties (COP1) in Berlin;
1996--July—Second Conference of the Parties (COP2) in Geneva;
1997—July/Aug.—Negotiating Session in Bonn reconvened in Bonn in October;

securing firm commitments from nations to reduce the emission of greenhouse gasses and mitigate the impact of global climate change.

Major Provisions of the Protocol:

The Protocol emanating from The Kyoto meeting was grounded in a number of basic principles. The first and most important of these was the use of legally binding emissions targets for the participating countries. The targets would be based on specified requirements including provisions for measurement, reporting and compliance. To the extent possible market forces were to be used to provide incentives for emissions reductions. This included mechanisms for emissions trading and joint implementation (groups of nations, e.g., the European Union).

The Protocol did not include mandatory targets for the Developing Countries; however, the intent was to continue to obtain commitments by all parties, meaning the Developing Countries. A deliberate decision was made to focus on the medium term (2010 to 2020) as a more realistic time frame within which to make progress in reducing greenhouse gasses emissions. To the extent possible the Protocol was to provide flexibility for countries to meet their targets in the most effective and efficient way possible given their situations and conditions.

Six specific greenhouse gasses were identified to be included in the national targets.[30] These included CO2, NOx, Methane and three fluorocarbons (HFCs, PFCs and SF6).[31] The 1990 levels of emissions were prescribed as a part of the Annex to the Protocol. Against this base, the percentage reduction would be calculated. The base levels for each of the Developed Countries was submitted to a technical body,[32] reviewed and when accepted it became the base emissions level for that country.

As an overall objective the Protocol calls for all parties to reduce their greenhouse gasses emissions 5% below 1990 levels by the 2008-12 time period. Within this overall objective, each of the Developed Countries (or group of countries) is given specific targets. For example, the European Union agreed to reductions 8% below 1990; Japan is 6% below 1990, while The United States is 7% below 1990 (or at 93% of the 1990 level of emissions). The Russian Federation and former Soviet States are referred to as Emerging Market Economies and their target is to remain approximately at the 1990 level.

Upon learning that the U. S. negotiators had agreed to limit emissions during the 5-year period (2008-12) to a level 7% below the 1990 emissions level, the critics of the Kyoto Protocol expressed dismay. They warned that if one assumed a business-as-usual trend, this would require a reduction of 31% by the year 2010 (midpoint). They contended that reductions of this magnitude would only be obtained through harsh measures that they believe would adversely effect our economic growth.

Others who supported the treaty responded that the 7% reduction would not present overwhelming problems. They contended that the U. S. will be able to rely heavily on carbon sinks and other provisions of the Kyoto Protocol (such as emissions trading) to meet the U. S. target. In their opinion, the actual

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December—Third Conference of the Parties (COP3) in Kyoto, Japan.
1998—November—Fourth Conference of the Parties (COP4) in Buenos Aires, convened to discuss the specific provisions for emissions trading, enforcement and other mechanisms.

[30] The three fluorocarbons added to the list of greenhouse gasses, slightly reduce the overall U.S. commitment and provides increased flexibility in reaching emissions reductions. Fluorocarbon emissions have increased significantly between 1990 and 1995 as they are used as a substitute for banned CFCs. Thus calculating fluorocarbons from a 1995 baseline, in effect lowers the overall U. S. emission reduction commitment by one percent.
[31] See footnote 3 for descriptions of the CFCs.
[32] The Subsidiary Body for Scientific and Technological Advice to the Kyoto Protocol.

reduction will probably be more like 2 or 3 percent.[33] In addition, they noted that the time period for performance (established as the average of years 2008 to 2012) provides some flexibility in reaching this goal. (These basic points of disagreement, pro and con, have become part of the debate that is beginning to unfold as we move toward a decision on ratification.)

Of particular interest to this paper is the treatment of commercial aviation (international flights) under the provisions of the Protocol. The Protocol states,

> "The Parties included in Annex I shall pursue limitation or reduction of emissions of greenhouse gasses not controlled by the Montreal Protocol from aviation…working through the International Civil Aviation Organization…."[34] (Omitted sections refer to marine bunker fuels and provide similar guidance.)

The only other references to aviation in the protocol relate to general provisions to minimize social and economic impacts of the recommended actions and provisions regarding military aircraft emissions under various conditions. (Information on the ICAO meetings will be discussed later in the section on "Impact on Aviation".)

The exclusion of Developing Countries from the limits imposed by the Protocol has been a matter of concern to the United States as well as a number of other Developed Countries. While recognizing the unique needs of these countries, securing meaningful participation of the Developing Countries remains a priority objective of the United States and presents a major obstacle to the ratification of the Protocol by the Senate. A form of participation is provided for through the Clean Development Mechanism (discussed below) and the introduction of energy efficient technologies for transportation, energy production and use, agriculture and forestry. Through this mechanism the Developing Countries can become involved in the Protocol agreement. It is not clear though that this form of participation will be viewed by many in the United States Senate as meeting the spirit of the Protocol.

Emissions Trading has been a key issue with the United States during the Protocol deliberations. Free market approaches have been the essence of the underlying philosophy adopted by the United States delegation in the Kyoto deliberations. The United States has pioneered the use of a free market approach as a way to control and reduce undesirable emissions of gasses such as SOx and is largely responsible for their inclusion in the provisions of the Kyoto Protocol. The U. S. position is that free-market approaches are the most efficient way to achieve the reductions needed to meet the requirements of the Kyoto Protocol. Structured effectively, emissions trading can provide a powerful economic incentive to cut emissions while also allowing important flexibility for taking cost-effective actions.

During the Protocol deliberations the European Union took a dim view of the free market approach. Some members of the community expressed concerns that the United States would buy its way to meeting the targets without making serious efforts to reduce domestic emissions. The Europeans favor mandatory approaches. The United States led the effort to reject the proposals to require all parties with targets to impose specific mandatory measures, such as energy taxes.

In addition to pushing for the emission trading provision, the U. S. also has reached a conceptual agreement with a number of countries including Australia, Canada, Japan, New Zealand, Russia and the Ukraine to create an umbrella group to facilitate a market for trading emission permits.

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[33] "Analysis of Kyoto Protocol", S. R. Fletcher, USIA Electronic Journal, April 1998.

[34] The Kyoto Protocol, Article 2, Section b, Paragraph 2. This provides little guidance as to how international aviation should be treated, however the reference to "The Parties' subtly implies that a country approach be followed. This would differ from the approach used for noise and NOx emissions previously addressed by ICAO; in those instances the regulations were placed on performance of new or modified aircraft or engines.

The Clean Development Mechanism (CDM) is another market mechanism championed by the United States. This mechanism allows Developed Countries to use certified emissions reductions from project activities in Developing Countries to contribute to their compliance to the greenhouse gasses targets. Certified emissions reductions achieved starting in the year 2000 can count toward compliance with the first budget period. This means that private companies in the developed world will be able to benefit from taking early action. As mentioned above, the CDM also serves as a method to engage Developing Countries to reduce or limit emissions.

A mechanism employed by the Protocol to reduce CO2 in the atmosphere is Carbon Sinks. Through natural biological processes plants take up carbon. If a country employs "direct, human-induced change and forestry activities" to enhance plant and tree growth, the carbon removed by this process can be used to offset emissions reductions. This process is encouraged because it both removes greenhouse gasses from the atmosphere and provides an incentive to limit deforestation. The land-use and forestry activities that qualify are limited, however, to those afforestation and reforestation initiatives that have been undertaken since 1990. They are to be measured as verifiable changes in stocks for the commitment period. (In this manner deforestation can be counted as a negative factor, that is, deforestation must be offset by additional emissions reductions.) Specific activities that may be included in this provision have not yet been identified.

The U. S. agricultural community is particularly concerned that the Carbon Sink provisions include farming practices that can retain carbon in the soil. Traditional plowing and tilling techniques disturb the soil and expose plant root matter to the atmosphere where it can decompose thereby releasing CO2 and CH4. Modern farming techniques have been developed that eliminate the need for these traditional methods thereby retaining the carbon content of the roots in the soil. In addition these new techniques are fuel-efficient and use fertilizers and herbicides more effectively. The agricultural community wants these reductions to be eligible for inclusion in the carbon sink mechanism.

While agreement was reached at the Kyoto Conference as to the general provisions and guidelines for the Protocol, many of the more contentious details for the implementation of the Protocol were deferred for later consideration. These details were addressed in Buenos Aires roughly one year after the Kyoto Agreement was concluded. This pause was designed to allow time for the participant representatives to meet and discuss the specific details for the "mechanisms". The hope was that progress could be made toward agreement on these important implementing details.

Buenos Aires:

A working meeting to develop the details for the key mechanisms identified in the Kyoto agreement was held in Buenos Aires in November of 1998.[35] The objective was to complete the negotiations on the details on mechanisms for emissions trading, verification methods, the Clean Development Mechanism[36] and Joint Implementation (whereby groups of countries act in consort to achieve their joint goals). While the Buenos Aires meeting was characterized as fruitful, many of the more important issues were deferred when agreement could not be reached on the details of implementation. The Convention of the Parties unanimously agreed to a two-year Action Plan, thereby buying more time to work out the details.

The emissions trading issue is of concern to both the United States and the European Union. The New York Times news account of the issues in the Action Plan contained the following assessment.

[35] The Buenos Aires meeting is referred to as the fourth meeting of the Convention of the Parties or in the UN lexicon as COP4.
[36] This allows Developed Countries to receive partial credits when supporting Developing Country measures to prevent greenhouse gasses emissions.

> "One particular obstacle in the way of eventually making emissions trading a reality is an insistence by the European Union, backed by some Developing Countries, that a limit be placed on the amount of a country's emissions reduction target that could be achieved through trading. The United States adamantly argues that this would rob the arrangement of its cost-cutting value and allow fewer reductions, worldwide as well."[37]

The Action Plan is slated to address the six agenda items requiring further deliberations. Detailed provisions for the three mechanisms mentioned above were included in the action plan. These are critical for meeting the national targets of many Developed Countries. Other items pending included questions regarding measurement, performance audits, and penalties for non-performance. These items are the more contentious issues that had been addressed only in concept in the Kyoto Protocol.

The meeting in Buenos Aires did have some successes. Negotiators agreed to set rules for enforcing the Treaty to discourage cheating and penalties for countries that do not comply, although the particulars of such rules were not completed. Very important to the United States, two Developing Countries, Kazakhstan and Argentina agreed to reduce emissions. They represent a first step toward participation by Developing Countries.[38] The conclusion was that the more difficult issues discussed above and the participation by the Developing Countries will be worked out prior to the Rio de Janeiro Ratification Meeting set for 2000. The delay provides time to draft language for the more controversial issues related to the mechanisms and secure additional signatures on the Protocol.

On November 12, 1998 the United States signed the Kyoto Protocol. Vice President Gore noted, "Our signing of the protocol underscores our determination to achieve a truly global solution to this global challenge." While the U. S. government indicated its support for the agreement, the accord is not legally binding until ratified by the Senate. The signing reinforces the administration commitment to the agreement and allows the United States to participate in negotiations to amend and revise the details of the Protocol.[39]

VI. Domestic Political Issues

At the top of the political concerns regarding the Kyoto Protocol are a complex of economic issues involving competitiveness of U. S. companies, loss of U. S. jobs to overseas competitors and a general dampening of U. S economic growth. Interwoven with these concerns are questions of both domestic and global equity, opposition to command and control approaches (and conversely a commitment to market-based solutions), and avoidance of the perception, or reality, of any new taxes.

The most difficult political issues are focussed on the potential economic and social impacts to various constituencies as well as the overall impact on the nation. These concerns are interrelated and surface in different forms at different times. Fairness is a primary concern; any agreement that is perceived to single out specific industries or groups of workers for harsh treatment will be unacceptable. The broad economic concern is the overall cost to the nation and our economy that may be imposed by the accord. This cost can not appear excessive in terms of the negative impacts to our economic growth and employment. Finally, there is the concern that despite these potential costs, the Protocol may not achieve its end objective of arresting global climate change. Many members of congress have expressed serious doubts

[37] New York Times, Nov. 14, 1998, "Key Questions Remain at Global-Warming Talks," W. K. Stevens.
[38] While these two Developing Countries were welcome news at the Buenos Aires Meeting, They are not likely to be considered "key Developing Countries" in the eyes of the Congress.
[39] Article 13 of the Kyoto Protocol states that 'those Parties that are NOT Parties to the Protocol, that is, are not signators, may participate in the proceedings as observers…, [however]…non-signators will not participate in decisions made by the Convention of the Parties (COP). [Furthermore] any non-signator who is a member of the Bureau of the COP, shall be replaced….' Thus had the United States not signed the Protocol it could be formally excluded from the negotiations to establish the details for the mechanisms.

that the protocol as crafted would achieve these objectives.[40] Given the political cost of enacting such a measure, it is essential that achievement of the goals be assured. Failure of the Protocol to pass muster in any of the above areas of concern will compromise ratification.

In this difficult political setting uncertainties and disagreements (or the appearance of uncertainties and disagreements) in the scientific community become leverage in the political debates. Scientific uncertainty provides a rationale for deferring the unpleasant political decisions that could mean inconvenience or economic harm to constituents. The safe solution is to call for more study and research and provide modest incentives to stimulate voluntary actions. This is where we currently find ourselves.

Global Equity:

The most visible challenge to the ratification of the Kyoto Protocol by the United States Senate is the issue of global equity. In the March 5, 1998 hearing of the Senate Agriculture Committee Senator Lugar stated, "The Kyoto Protocol, in its current form, is highly controversial and unlikely to be ratified by the Senate. The key issue is the failure of the major Developing Countries to participate in controlling their emissions, particularly countries like China, India, and Mexico. China, specifically, has expressed adamant opposition to limits of any kind."

Senator Lugar is not alone in his opposition to an accord that does not include some commitments from major Developing Countries. Many of the Developing Countries are rapidly growing their economies and this category of nations is predicted to become the largest emitters of greenhouse gasses within the next 20 years. Estimates from a number of sources forecast that by the year 2020 emissions from Developing Countries will exceed those of the Developed Countries. Furthermore, regulating the emissions of only the Developed Countries could lead to the migration of energy-intensive industries (chemicals, steel, aluminum, etc.) from the industrialized countries to those growing Developing Countries. With this migration would be the loss of many "good paying jobs" in manufacturing industries. Such a prospect raises the "flipping burgers" syndrome reminiscent of election campaigns of the early 1990s when many manufacturing jobs were popularly portrayed as being drained from the United States.

Responding to this fairness issue and concerned that his own constituents (coal operators and miners) might also be singled out to bear an excessive burden, Senator Robert Byrd of West Virginia in June of 1997 offered Resolution SR 98 for consideration by the Senate. The resolution states--

> "[Be it resolved] that the United States should not be a signatory to any protocol to, or other agreement regarding, the United Nations Framework Convention on Climate Change of 1992, at negotiations in Kyoto in December 1997 or thereafter which would: (1) mandate new commitments to limit or reduce greenhouse gas emissions for the Annex 1 Parties, unless the protocol or other agreement also mandates new specific scheduled commitments to limit or reduce greenhouse gas emissions for Developing Country Parties within the same compliance period; or (2) result in serious harm to the U. S. economy."

This warning shot was fired six months before the meeting in Kyoto in December of 1997. The resolution was passed on the Senate floor by a vote of 95 to 0. The margin of the vote gives some insight into the strength of the equity issue. Even senators who were strong supporters of the Kyoto Protocol were unwilling to oppose the resolution. The importance of the senate vote is obvious; the senate must ratify any such agreement before it is binding on the United States. By this vote the senate put the administration on notice that Developing Country participation was essential. The vote also strengthened the administration's hand in its efforts to entice Developing Countries to participate by putting the world

[40] Monitoring Environmental Progress, World Bank.

community on notice that the Senate of the United States would not ratify the accord without such participation.[41]

Recognizing the obvious importance of this vote, the administration is working hard to encourage Developing Countries to make commitments to limit or reduce their emissions. Before it will submit the accord to the senate for ratification, the administration has acknowledged that it needs to have meaningful participation from Developing Countries.

Economic Concerns:

The prospect of broad negative economic impacts is a matter of concern to many in the business community. There have been numerous economic predictions from both opponents of the Protocol and its supporters. These run the spectrum from little or no economic impact to economic disaster. Not surprisingly most of these tend to support the position of the group issuing or quoting the forecast. All of these predictions are highly speculative in nature and incorporate a variety of assumptions that strongly influence the outcome.

The overall economic costs to the United States of implementing the Protocol as measured in terms of economic growth and employment opportunities are admittedly difficult to gauge. Uncertainties regarding the specifics of the mechanisms for executing the protocol only add to the difficulties of developing a realistic assessment of the cost. Estimates from the Energy Information Agency[42] economic model give a broad range of economic costs ranging from $61 billion to nearly $400 billion in the year 2010. These forecast cases depend on a host of assumptions about technology, tax policy, carbon prices, overall economic growth, and the details of the Protocol mechanisms. The various cases alter these basic variables to assess the sensitivity of various assumptions and their impacts on the United States economy. The low side estimates, while significant, are likely to be within the range of an acceptable cost to the body politic. The higher side estimates are likely to raise major concerns and question the political viability of the proposed solution.

The IPCC in its Second Assessment took a more optimistic view regarding the potential of new technology and the overall cost of achieving the target emission reductions. They stated the view of their members that--

> "Despite significant differences in views, there is agreement that energy efficiency gains of perhaps 10 to 30 percent above baseline trends over the next two to three decades can be realized at negative to zero net costs. With longer time horizons, which allow a more complete turnover of capital stocks, …this potential is much higher."[43]

The estimated costs of mitigation vary widely and are laced with assumptions, scenarios, policy instruments and time criteria. The projected benefits of taking such actions, expressed in dollar terms, are even more primitive, perhaps by an order of magnitude. The reality would seem to be that we have a grasp of the direction but not the magnitude of either the costs or the benefits.

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[41] Many Developing Countries have argued that the Berlin Mandate specifically excluded them from limiting their emissions of greenhouse gasses. Therefore most feel they have no obligation to take unilateral actions to reduce greenhouse gasses.
[42] The EIA is an entity of the Department of Energy. It has built and maintained a sophisticated energy-economic model for forecasting the relationships between energy production and use, energy prices and general economic measures. One of the key inputs for these forecasts was the cost to remove a ton of carbon from emissions.
[43] IPCC—Second Assessment, Section 7.

In a paper entitled, "Climate Change Policy After Kyoto," the authors after wrestling with the wide variety of cost estimates to implement the Protocol, commented:

> In our judgment, neither extreme view is correct. The likelihood is substantial, however, that the proposed target and timetable will impose significant costs on the United States and the global economy, even after accounting for new technology stimulated by domestic policies.[44]

Business Opportunity or Threat:

In the business community there appears to be a growing fissure between those who consider the Protocol a threat and those who view it as a potential business opportunity. These diverging views are likely to have an influence on the political dynamics surrounding the ratification of Protocol by the United States. Just how important an influence this split will have, is difficult to gage at this time, nevertheless, it indicates there will not be "one business position" on the accord.

A growing number of companies are beginning to focus on how to reduce greenhouse gas emissions. Electric utilities executives, oil company executives (Texaco, Sun, Shell, and British Petroleum) and others have begun to take actions to reduce emissions and explore business opportunities to assist other companies reduce their emissions. Sun Oil executives noted that "…there is sufficient scientific concern about man-made climate impacts to justify initiation of prudent mitigation measures now." Peter Bijur, CEO of Texaco recently told financial leaders that "…the debate really isn't about the science anymore. It's about what companies are doing, and what they are doing is to look at the next generation of technologies and improving efficiencies of operations, reducing emissions of refineries and things like that." Texaco spokespersons added that Bijur's comments were about using Texaco's technology and other strengths to be more competitive into the next century. Automobile researchers are already working on a variety of new vehicles that offer maximum mobility and minimum emissions. The big three and Toyota are involved with the Department of Energy on a project entitled, a Partnership for a New Generation of Vehicles. A number of other companies are pursuing aggressive programs to reduce fuel consumption. As one industry spokesperson noted, "This is not only sound environmental policy it is good business."[45]

Paul Tebo, vice president in charge of environmental issues at DuPont commented that he believes big business will be faster to match public sentiment on global warming than two decades ago, when businesses were slow to respond to growing public concerns about the environment.

Manufacturing industries are not the only ones who are sensitive to the climate change issue. The insurance industry is anxiously watching the global climate issue. The cost of insurance claims from major storms and hurricanes in the United States during the 1990's has reached into the tens-of-billions of dollars. The industry views climate change as a serious threat. The prospect that global warming could mean rising sea levels and more frequent and more severe storms caught the industry's attention. Prudence dictates that precautionary actions be taken to minimize their exposure and protect their solvency.

In addition to individual companies, the Pew Trusts have formed "The Pew Center on Global Climate Change" for the purpose of providing a credible voice on the defining issues surrounding global climate change. Twenty major U. S. companies have come together to form the Center for the purpose of taking actions to address the problem of climate change. The Center will undertake studies and analyses on this and other critical issues. The Pew Trust has long been a strong supporter of free enterprise and

[44] R. J. Kopp, R. D. Morgenstern, and M. S. Toman of Resources for the Future.
[45] USIA Electronic Journal, "Two Companies on Leading Edge in Emissions Trading," Smith and Lambert, April 1998.

conservative business views. The Pew Center's interest in this issue provides an activist voice on global climate change that resonates within the business community.[46]

Despite the emergence of some industry leaders who view this as a business opportunity, the predominant view of the business community is more cautious. Some industries feel threatened, as do many of their workers. The Bituminous Coal Operators Association and the United Mine Workers of America joined forces to attack the administration for supporting the Protocol. They further argued that the cost of household electric bills, loss of economic growth and unemployment would be much more severe than estimated by the Administration.[47]

Other more broadly based business groups, such as The Business Roundtable has taken a more reserved, but nevertheless, opposition view of the Protocol. In its Task Force Report entitled "The Gap" they stated their position. "The Business Roundtable feels it is imperative that a public dialogue take place on the major issues highlighted in our Gap Analysis before the Protocol becomes the law of the land and government agencies begin to write regulations."[48] The Business Roundtable report focussed its analysis on a number of provisions in the protocol that, if unchanged, would present a threat to the United States economy and to the business community.

Perhaps Red Cavaney, the head of the American Petroleum Institute, put his finger on the dichotomy in industry when he noted, "…once you move beyond industry's concerns over the Kyoto agreement, you get different views from industry officials on how individual companies are going to implement emissions reductions…."[49]

Market Based Solutions:

How can we plan and implement programs to address climate change in ways that are fair to different industry sectors and members of the workforce, maintain our national competitiveness in the international market place and address greenhouse gas emissions? This is the question facing many politicians. In the United States, much of the discussion about market based solutions has implicitly been directed at emissions trading schemes, that is, the purchase of emissions rights from domestic or foreign sources based on prevailing market prices. The European Union and some Developing Countries view market forces somewhat differently. While recognizing a role for emissions trading, they are inclined to favor the use of energy taxes to provide an economic incentive for businesses to reduce their energy use and thereby the emission of greenhouse gasses.

Recognizing the American view of market forces and the enormous economic resources of the United States, the European Union and some Developing Countries have proposed that emissions trading limits be established.[50] They fear that without limits the United States will bid up the price for emissions rights and drive out other countries. This will allow the United States to meet its targets without taking specific actions to reduce emissions. To prevent this, the Europeans have proposed that limitations be placed on a country's rights to purchase emissions. (This issue became one of the stumbling blocks at the Buenos Aires meeting.) The United States and some other Developed Countries contend that placing such limits on the purchase of emissions would rob the free market of its effectiveness.

Many members of congress have espoused their commitment to market based solutions as the only acceptable method of achieving emission reductions. They have rejected taxes, energy price increases,

[46] For further information, The Pew Center on Global Climate Change web site can be reached at www.pewclimate.org
[47] Reuters August 6, 1998.
[48] From a report of the Business Roundtable entitled, "The Kyoto Protocol: A Gap Analysis," June 1998.
[49] Op cit, USIA Electronic Journal.
[50] New York Times, Nov. 15, 1998, "Deadline Is Set for Rules to Cut Emissions," by Wm. Stevens.

and command and control approaches as ineffective and counter productive in terms of our national commitments to economic growth and full employment. They have rightly identified that our environmental problems are related to our need for energy. And they have made the linkage between our energy needs and our emissions of greenhouse gasses. They also recognize that we cannot defer taking action indefinitely. Nevertheless, the difficulty for politically elected officials is the obvious--market based solutions call for increases in energy prices/costs through some means. This increase is politically unpalatable.

Along this line excerpts from the statement of Senator Harkins (an advocate of emissions reductions) is very insightful. While calling for action to address the problems of climate change, Senator Harkins stated that "…waiting for certainty may leave us no time to address the problem." "…Our commitments can be met by taking advantage of the market-based provisions offered in the Kyoto Accord and [various] types of tax incentives to increase energy efficiency…." Perhaps fearing that some might pick up on the link between market-based solutions and higher energy prices, he quickly injected, "Congress is in a pivotal position to ensure that a policy that requires a major increase in energy prices is never enacted."[51]

It is obvious that the biggest incentive for improving efficiency in energy use is higher energy prices. However, this negative market "incentive" is politically distasteful to all segments of the political spectrum and is not likely to be given serious consideration. The challenge facing the policy makers is to design market mechanisms that will result in timely, meaningful actions at the lowest possible cost that do not take on the appearance of a tax nor do they look like an energy price increase. To date few proposals with these attributes have entered into the public debate.

Recent public opinion polls have indicated a growing concern about climate change and some willingness to accept some inconvenience to reduce emissions. Just how much inconvenience and economic penalty the public will accept is unclear. Public willingness to accept significant burdens to reduce greenhouse gas emissions has not been put to the test.[52]

Risk of Inaction:

What are the consequences if we fail to act and meet the challenges of climate change? In a recent Policy Statement, the American Geophysical Union (the most broadly based professional organization in earth and space science in the United States) noted that there was "a compelling basis for legitimate public concern" about climate change. They noted that "scientific uncertainty about the problem does not justify inaction in coping with it."[53] The geophysical union went on to note that 'there is no known geologic precedent for the conversion of the earth's crust into atmospheric carbon dioxide on such a large scale as is being done through the burning of vast quantities of fossil fuels'.

In response to this statement, the Competitive Enterprise Institute, a public policy group that promotes free enterprise and limited government, stated that the geophysical union, by making a judgment favorable to the Clinton administration's policy of action on global warming, had "crossed the line separating science and advocacy." Such accusations provide a glimpse of the emotional content of the debate that is likely to surround ratification.

Need for Early Action:

The Administration decision to delay submitting the Protocol for ratification by the Senate until

[51] Hearing by the Senate Agriculture Committee, March 5, 1998.
[52] From a study prepared by Resources for the Future and contained in the USIA Electronic Journal of April 1998.
[53] Article in the New York Times, "Scientists Warn Against Ignoring Climate Change," William K. Stevens, January 29, 1999.

there is significant developing country participation is a decision driven by political necessity. Unfortunately, this will have the effect of compressing the time available to comply with the requirements of the accord (should it be ratified). Looking at the steps that will be required to enact this Protocol in the United States the dilemma becomes obvious. There are a number of scheduled steps that trigger the necessary activities related to emissions reductions. If it is optimistically assumed that the mechanisms for emissions trading, cooperative development mechanisms, and carbon sinks will be agreed upon, and the compliance and enforcement issues settled. And, one also assumes that there are a sufficient number of Developing Countries committed to the Protocol to assuage the concerns of two-thirds of the Senate. And, with equal optimism, that ratification will occur in the year 2000, then what remains to be done before a working system is in place?

First, the United States Government would have to establish rules and guidelines for emissions trading with other Annex I countries and for the cooperative development mechanisms. Second, Congressional consideration and enactment of legislation to implement climate change provisions would be required. (Along with the required time for the numerous committees in both houses to conduct hearings and agree on legislative language.) Third, following passage of the needed legislation, rulemaking by appropriate departments and agencies would necessarily follow. Finally, implementation plans would have to be developed. Emission targets would have to be assigned to various industry groups and distributed to individual companies within such groups.

Both proponents and opponents are concerned about the delays that are likely to be encountered before the protocol is shaped into a working system. Each of these steps is a lengthy process under the best of political conditions. If these laws, regulations or allocations are challenged in the courts, then the process would likely be delayed even longer.

The Pew Center report, "Early Action and Global Climate Change," presented a very pessimistic view of the timing of the events needed to implement the protocol. They contend that some form of 'early action plan' needs to be enacted and put in place. They summed up their assessment as follows,

> "There is little prospect that the United States will reach a political consensus on whether or not to ratify the Kyoto Protocol before 2001. Congress likely will need several additional years thereafter to enact into law a comprehensive regulatory framework for implementing the treaty obligations. Greenhouse gas reductions could be further delayed while federal agencies develop specific implementing regulations for affected industry sectors. This extended period of uncertainty as to whether the Protocol will be ratified and how it will be implemented may deter companies otherwise willing to reduce their greenhouse gas emissions from making those reductions. An early action crediting program provides a framework that permits companies to make immediate greenhouse gasses reductions while the major international and domestic policy issues are debated."[54]

The report concluded that a working system may not be in place until the middle of the first decade of the twenty-first century. This would leave only three or four years to take the necessary actions to show progress and meet the targets set for the 2008 to 2012 time frame. (In addition, Article 3, Paragraph 2 of the Protocol states, "Each Party included in Annex I shall, by 2005, have made demonstrable progress in achieving its commitments under this Protocol." If mid decade is a realistic date for a working system, then no discernable progress can be expected by 2005.) The more compressed the response time the more costly remedial actions are likely to be. This prospect has lead to some actions on the part of the Administration and in the legislative arena.

Concerned that the uncertainty would delay actions by industry and individuals and make it impossible to reach the targets, Senators Mack and Lieberman introduced S. 2617, The Credit for Early Action Act in

[54] The Pew Center on Global Climate Change, "Early Action and Global Climate Change", p8.

October 1998. This Bill would amend the Clean Air Act to authorize the President to enter into legally binding early action agreements with any person for reduction credits usable beginning in the first compliance period if such a person reduces greenhouse gas emissions or sequesters carbon before 2008. The bill limits creditable reduction to either December 31, 2007, or should the agreement be delayed, to the earliest date on which credit may be earned under an international agreement. The bill was introduced by Senator Chafee (R-RI), Chairman of the Committee on Environment and Public Works, thus adding to the political support for this measure.

The concern of these Senate members is that key provisions of the Protocol have not been established and it appears that they will not be resolved in the near future. They include the treatment of carbon sinks, mechanisms for emissions trading, and clean development mechanisms. These three provisions are critical to a politically acceptable accord, and until these are specified, the Protocol will not be put before the Senate for ratification. This dilemma leaves little time to achieve the necessary reductions before the 2008-12 period. Without resolution of the details for these three mechanisms, industry will be hesitant to take actions lest they be excluded from counting toward their target. They need assurances that investments made to reduce emissions will be counted as part of their contribution to emissions reductions. This requires some legislative assurances. The Mack-Lieberman bill is intended to provide the needed assurances to industry and to encourage early action. While the international negotiations continue, domestically there needs to be some details on how the targets in the Protocol would be distributed among the various sectors of the economy.

Shortly after the introduction of the Early Action Bill, the Convention of the Parties met in Buenos Aires to address these and other issues. The participants were not able to resolve differences and reach agreement. There is reported to be a general philosophical disagreement between the U. S., the European Union and many Developing Countries regarding the use of market solutions vs. "command and control" approaches. Many U. S. Senators have expressed the opinion that a Protocol that relies on "command-and-control" mechanisms will never be accepted by the Senate.[55] Work on the resolution of these questions will continue and the recommendations will be presented at the Rio meeting in 2000. This delay in reaching consensus on the operating mechanisms reinforces the need for the Mack-Lieberman Bill.

Opinion Polls:

Like most other political issues of our day, global climate change and the Kyoto Protocol have not escaped the watchful eye of the pollsters. As is often the case, interpreting the results of such polls is often subjective and at times confusing. The results of the opinion polls taken on global climate and the Protocol are excellent examples. The poll results from the Wirthlin Worldwide polling organization taken on election day (1998), found that more than six in ten Americans believe the climate change treaty negotiated in Kyoto will be expensive for American households and should not be implemented. However, in spite of a lack of general support for the treaty, 54% of those polled said that President Clinton should immediately sign the treaty and submit it to the Senate for debate next year.

For this writer these poll results suggest four possibilities. Either the public is totally ignorant about the Protocol and does not associate the contents of the Protocol with the signing of the President. Or conversely, they are very sophisticated and understand the subtleties of the workings of the treaties and recognize that signing the treaty does not commit the United States but does allow us to participate in proposing changes to its contents. Or perhaps, they want a general public discussion and debate on the

[55] From Global Issues, Industry Shifting Gears—Seeking Solutions; this is from the U. S. Information Agency, Electronic Journal, April 1998, Jim Fuller author.

treaty and feel that submitting it to the Senate for consideration will trigger such a debate. Finally, it could be some mix of all of the above.

An important discovery that one public opinion poll has uncovered is the surfacing of partisan politics in the opinions of the public. This is a worrisome trend given that partisan bickering has been so emotional and counter productive in recent years and has shed more heat than light on important issues. The Resources for the Future report, "The Impact of the Fall 1997 Debate About Global Warming on American Public Opinion," contained the following summary about the efforts of both sides to educate the public on the climate change issue:

> "…. despite public education campaigns in the fall of 1997 about global warming by groups on both sides of the climate change argument, neither side can claim many more supporters after the fall than before. The chief effect of these campaigns and news coverage, the survey's findings indicate, was to deepen division in the American public along political party lines. More Democrats believe global warming exists and will have undesirable consequences, while more Republicans believe global warming is not a reality and will not have undesirable consequences.[56]

Should the debate over ratification of the Protocol take on partisan overtones, it would make it very unlikely that the needed two-thirds vote could be achieved in the Senate.

VII. Research and Technology:

The IPCC's Second Analysis notes that there are significant opportunities to reduce greenhouse gasses. The report states that in the next 100 years the world's commercial energy system will be replaced twice, thus affording ample opportunities to replace the existing systems with capital stock that is more efficient and emits lower quantities of greenhouse gasses. These cycles of capital replacement provide opportunities for more energy efficient technologies for agriculture, manufacturing, utilities and transportation. The life expectancy of many of these capital investments can be as long as 50 to 75 years, therefore, it is important that action be taken quickly before capital commitments to existing off-the-shelf technologies preclude the use of new, more efficient technologies for many decades. This is of particular important in the growing economies of the Developing Countries.[57]

According to the IPCC report, "it is technically possible to realize deep emissions reductions in the energy sector within the next 50 to 100 years using alternative strategies, in step with the normal timing of investments to replace infrastructure and equipment as it wears out or becomes obsolete." The report went on to discuss options for the use of fossil fuels noting that there are a number of technologies that are critical to success. Heading the list are technologies for reducing fugitive emissions of natural gas and more efficiently converting fossil fuels to useful energy through combined cycle processes. Other opportunities to reduce emissions can be realized by fuel switching to less carbon intensive fuels, e.g., from coal to natural gas. More technically challenging opportunities reside in the decarbonization of flue gasses and carbon dioxide storage. Finally, switching to nuclear energy and renewable sources of energy through the use of solar, biomass, wind, hydro and geothermal energy provides additional opportunities to reduce emissions. While the IPCC report presents an optimistic view of the vast opportunities to reduce emissions, one must be mindful that not all of these non-fossil options are considered politically or economically viable at this time.

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[56] Results of a survey conducted by researchers in Ohio State University Survey Research Unit, based on opinions before and after the Kyoto Protocol agreement.

[57] IPCC Second Assessment Synthesis of Scientific-Technical Information…, Section 5, Technology and Policy Options. The IPCC Third Assessment is due to be completed in late 2000 or early 2001.

The report continues that while such technology driven reductions in emissions are possible and can be economically feasible; a number of impediments must be overcome if this technological harvest is to be realized. The deployment of more efficient technologies will require initiatives to counter the lack of information and overcome cultural, institutional, legal, financial and economic barriers. In addition these new technologies must not only be more efficient, but they must also be compatible with the economic needs of both the developed and Developing Countries.

The Clinton Administration indicated its predisposition toward technological solutions when it proposed a modest step to expedite the development and deployment of new technologies just prior to the Kyoto meeting. In October 1997 the Administration introduced a three-stage proposal on climate change. The first stage of this proposal is intended to 'put the nation on a smooth path to reducing greenhouse gasses through research and development and tax credits for deploying new, energy efficient technologies'. This stage included $3.6 billion for tax incentives for deploying the new technologies and $2.7 billion for research and development. The research funds were spread over a five-year period. Energy efficient buildings, transportation, industrial processes and electric generation were identified as the principal targets for the tax incentives. Details for the other stages of the plan are not yet available.

The tax credits worked in conjunction with some Early Action Legislation might prove effective. However, the amount of the tax credit is quite small and is likely to have only limited impacts on our $8.7 trillion dollar economy[58].

Current research programs directed at climate change are centered in the Department of Energy and focussed on energy efficiency and energy forms that are low emitters. These programs have had some successes in developing more efficient methods of electric power generation and for more energy efficient buildings. Major programs are also on going to develop automobiles that are more energy efficient and have much lower emissions. Likewise programs have had some successes in improving the energy efficiency of various manufacturing activities. Much of this work is undertaken at the National Laboratories, private research institutes, such as the Electric Power Research Institute, and university laboratories throughout the nation. EPA also has major research efforts underway to reduce emissions of various greenhouse gasses.

In recent years many industrial companies have made major improvements to their operations to reduce energy use and control emissions of all types that pollute land, rivers and the atmosphere. Many of these steps have been undertaken in anticipation of the application of ISO 14000, the International Environmental Management Standard. Requirements for a company to be ISO 14000 Certified in order to compete for some contracts or market certain types of products have spurred action on the part of many U. S. companies. The provisions of ISO 14000 require that businesses manage their operations in an environmentally acceptable manner to promote sustainability. This includes minimizing emissions of all kinds. Such management approaches often create innovative processes for designing and manufacturing products that eliminate or minimize waste streams or substitute materials to avoid waste or spoilage. These innovations use systems approaches to manage, design, manufacture and transport their products to minimize pollutants, energy use, and emissions. Starting in the second half of the 1990's, these standards are being used extensively both in the United States and abroad.

Perhaps the most positive news comes from those industries that are looking at the Climate change issue as a business opportunity. These companies perceive the threat of climate change as a call for new technologies that will reduce or eliminate emissions of greenhouse gasses, reduce operating costs and in the process increase profits. Clearly this form of incentive can do much to address the greenhouse problem.

[58] Department of Commerce estimate of the United States Gross Domestic Product for the last quarter of 1998.

If the United States is to achieve its target of emission reductions, then technology development and emissions trading will have to be the cornerstones of our strategy. Based on most of the evidence, approaches that rely on reduced economic growth, consumer deprivation, major taxes on energy, or command and control enforcement will not be politically palatable. With effective leadership, small amounts of costs and inconvenience might be tolerated. Nevertheless, the body politic is not ready to accept significant costs or major inconveniences that negatively effect the lifestyle of most Americans. This is especially true when there are significant voices of dissent that assure us that there is no problem and when the problem itself lacks a sense of immediacy. As a technological society we still believe there must be a silver bullet that will solve the problem.

VIII. Aviation

The Kyoto Protocol addresses the philosophical underpinning and provides the structure of the international agreement among the participating nations. In so doing, it confines its efforts to the broader issues of overall targets for the parties, the tools to be employed to achieve these targets, the roles of the organizations, and the general ground rules to be applied. In setting this structure the Protocol uses a country or nation as its basic entity. In the protocol little is said about specific industries or groups of industries. There are, however, two exceptions. These are maritime transportation and international air transportation. Both have unique characteristics that place them outside the normal country or national boundaries. In significant measure these industries move across these national boundaries as a matter of course. They are the vehicles of trade and travel.

International Civil Aviation Organization (ICAO):

Recognition of the unusual nature of international civil aviation and the difficulties of assigning their emissions to individual countries, the Protocol transferred the responsibility for developing some means of addressing civil aviation to the existing international organization. The International Civil Aviation Organization (ICAO) is the responsible United Nations organization for overseeing the operation of and establishing the basic ground rules for international aviation. Consequently, in the Kyoto Protocol Article 2, Paragraph 2 states,

> "The Parties included in Annex I shall pursue limitation or reduction of emissions of greenhouse gases not controlled by the Montreal Protocol from aviation and marine bunker fuels, working through the International Civil Aviation Organization and the International Maritime Organization, respectively."

The Protocol continues that these 'policies and measures [shall be implemented]… in such a way as to minimize adverse effects, including the adverse effects of climate change, effects on international trade, and social, environmental and economic impacts….' The Protocol further suggests that this role will be carried out in conjunction with the Conference of the Parties and be consistent with other activities previously undertaken by ICAO.

Headquartered in Montreal, the ICAO was created in 1944 to address the constantly evolving challenges facing civil aviation, particularly in the area of flight safety. ICAO is a specialized agency of the United Nations with responsibility for all aspects of international aviation. The ICAO representatives come from civil aviation departments or authorities whose mandate is to promote the development of civil aviation.

Over the years its areas of responsibility have expanded with the growth of aviation and the recognition of new problems facing civil aviation. "It is the United Nations Specialized Agency responsible for establishing international standards, recommended practices and procedures covering the technical,

economic and legal fields of international civil aviation operations."[59] Among its many and varied objectives, ICAO is responsible for the 'recognition of and response to environmental concerns.' Given the special expertise and knowledge surrounding the aviation industry, ICAO was the logical organization to address greenhouse gas emissions related to civil aviation. The coordination of aviation emissions strategies would need to be compatible with many other operating objectives of aircraft such as safety, air traffic control, performance, and efficiency of operations.

While ICAO was the logical organization to address international aviation emissions of greenhouse gasses, the evidence suggests that the organization had scant early warning that it would be given this assignment. In May of 1997, seven months before the Kyoto Protocol was adopted, the ICAO issued its new Strategic Action Plan. A press release discussing the plan identified 43 key activities that were to be the core of the future ICAO program. Only one mention was made of any environmental issue; that was in reference to an assessment by ICAO of economic regulation of international air transport relative to environmental protection.[60] (While no elaboration is given in the plan, this is presumed to be charges or penalties for noise or NOx emissions from aircraft when arriving or leaving airports.)

In the early 1980's ICAO established standards for the control of aircraft engine emissions through an engine certification program. These standards, contained in Vol. II, Annex 16 to the "Convention on International Civil Aviation" established limits on nitrogen oxides, carbon monoxide and unburned hydrocarbons from new engines during the landing and take off (LTO) cycle. Subsequently in 1993 and again in 1995 the Committee on Aviation Environmental Protection (CAEP pronounced 'cape') recommended further tightening of the certification requirements, however, some member states did not support these actions and they were tabled.

In April 1998 these recommendations were amended and were finally adopted by consensus and sent to the ICAO Council. The amended restrictions on NOx were slightly reduced from the originally proposed restrictions for engines with higher-pressure ratios. Nevertheless, the adopted standards call for a 16% reduction of emissions of nitrogen oxides. The standards were adopted in early March of 1999 and will become effective in 2004. In addition, a broad agreement on international aviation emission standards is anticipated at the next ICAO general assembly to be held in September of 2001. If agreed upon, these also could become effective in 2004. CAEP is also looking into other ways to limit emissions including new measures for engine certification that would include the climb and cruise phases of flight. Previous standards have been based on the performance during the take-off and landing cycle.

According to Aerospace America, "the new driver to CAEP's work is the Kyoto Protocol." The article further notes, that "the agreement imposes binding targets on the signatory governments. While it is for the governments themselves to decide where to reduce emissions, ICAO has been given the mandate to take action on international civil aviation emissions."[61]

The charge accompanying the Protocol has lead to some interesting activities by some of the working groups within CAEP. For instance, The Market-Based Options Group is looking at emissions charges based on actual emissions, a possible fuel tax (with options on how the revenues should be used) and emissions trading for aircraft. The potential reaction of signatory governments (many of whom judiciously guard their authority to levy and collect taxes) to a recommendation by CAEP that new taxing and spending programs be imposed, is intriguing.

[59] From the ICAO Strategy Action Plan, issued in 1997.
[60] ICAO News Release on the Strategic Action Plan, May 22, 1997.
[61] Aerospace America, February 1999, article entitled, "New Emission Charges Will Impact Manufacturers."

Other approaches being discussed by ICAO involve capping emissions for international aviation at some level, and requiring more efficient aircraft be deployed to permit growth in air traffic. Some believe that a reduction in greenhouse gasses of more than 5 percent below current levels would be required to meet the Protocol targets. While a firm ceiling on emissions from international aviation has been discussed, as yet there have been few specifics released as to what this might be or how it might be implemented or applied.

It is felt by some that any short run agreement on emission limits should not create too severe a technical problem for engine manufacturers. Technologies for Dual Annular Combustors and other developments, such as, Twin-annular Preswirl (TAPS) either are available or anticipated to be available in the near future. The main concern will be to make sure that improvements in one area do not lead to increased emissions in another. Another important consideration is that these new technologies be brought to the market in a cost-effective way.[62]

Local and National Charges/Taxes:

ICAO has been designated to recommend the rules for international aviation emissions as per the provisions of the Protocol; however, other players are at work while ICAO is engaged in its deliberative process. In a recent news account it was noted that the Zurich and Geneva airports both levy emissions charges on airlines serving the region. In addition, "Norway began imposing an emissions tax on aviation fuel this year (1999), based on 100 Kroner/tonne of carbon dioxide released. This equates to 0.26 Kroner/liter of fuel and is the first time any state will have introduced such a tax." This is equivalent to roughly 10 cents (US) per gallon of jet fuel.

The article went on to note that the appearance of these types of charges or taxes has increased interest in the double-annular combustor (DAC). DAC engines are reputed to cut emissions levels by up to 50% over conventional engine combustors. This provides a financial incentive to choose the more complex system. Swiss Air and Austrian Airlines have been flying with the DAC since 1995. Other European airlines that have recently shown interest in this technology include SAS, Finnair, Edleweiss, and Sabena. Stockholm and nine other Swedish airports also impose an emissions levy on airlines, although they use different definitions of pollutants. [63]

Taxes on international civil aviation fuels have been a concern to ICAO. Its founding Convention (1944) "provides that fuels… retained on board an aircraft… shall be exempt from customs duty, inspection fees or similar national or local duties and charges."[64] At the same time there has been the recognition by ICAO that there are legitimate charges that can be levied to provide for aviation. The ICAO position is based on the distinction between a charge and a tax. They regard charges as levies to defray costs of providing facilities and services for civil aviation, where as taxes are levies to raise general revenues by the state or local governments, such tax revenues not being applied to support aviation needs. All tax related measures approved by ICAO require a consensus of the members.

As early as 1951, ICAO established policies regarding the imposition of taxes on aviation fuels for international flights. The recommendation on fuel taxation provided for reciprocal arrangements between states. Airlines of a state involved in such an arrangement would be exempt or eligible for a refund of taxes on fuels taken on board at the final international airport of call in the customs territory of the other

[62] Ibid.
[63] Ibid. p4. The article refers to the CFM56 engine as the Double Annular Combustor; the GE90 engine refers to their version as the Dual Annular Combustor.
[64] Appendix B. The ICAO Position on Taxes and Charges. Contained in "Policies and Measures for Common Action."

state. This recommendation was broadened to include all such ports of call, not just the final airport.[65] It was subsequently adopted as an ICAO Resolution.

In 1996 ICAO recognizing the growing interest of member states to establish some form of environmental charge, adopted a resolution to seek to identify a rational common basis on which States may introduce such charges. [ICAO] "Strongly recommends that any environmental levies on air transport which states may introduce should be in the form of charges rather than taxes and that the funds collected should be applied in the first instance to mitigating the environmental impact of aircraft engine emissions…." The Resolution gave a number of examples of the kinds of costs that should be considered and included such items as specific damage caused by the emissions; scientific research into their environmental impact; or research to reduce the impacts through developments in technology and new approaches to aircraft operations.[66] The emissions charges issue is under investigation by CAEP; they are working to understand and quantify the impacts then determine the best method for reducing their impact. The guidance to CAEP further stated that both regulatory measures and charges might be effective instruments in reducing emission levels. It did not specify which of these would be more appropriate.

By acknowledging that environmental charges can be effective in reducing emissions, the guidance language to CAEP appears to have opened the door for such charges. The actions by Norway and several of the European airports appears to be the first round and environmental charges in other countries and at other airports are likely to follow. This situation will probably impact U. S. airlines flying in international airspace. It could also impact the aircraft purchasing decisions of these same U. S. airlines.

The actions being taken or contemplated in Europe raises questions about the driving forces that are likely to influence the ICAO decisions relative to aircraft emissions. While the Kyoto Protocol has triggered action on the part of ICAO to address aircraft emissions, the actions of the European Airports and some governmental entities appears to be lending an air of urgency to that assignment. In the final analysis these "other players" might exert more influence on the actions proposed by ICAO than would the Kyoto Protocol.

IX. Aviation in Perspective

When looking at Global Climate Change in a broad perspective, it is easy to lose sight of aviation. In all the provisions of the Kyoto Protocol and the surrounding documents, there is only a short brief paragraph assigning the development of provisions for international aviation to the ICAO. While little was said about aviation in the Kyoto discussions, even less has been said about international or domestic aviation in the literature and debates in the United States. It is absent from news articles and editorials, congressional testimony and the overall debate of global climate change. For example, NASA authorization hearings in the House of Representatives in 1998 (not long after Kyoto) failed to mention emissions or climate change in reference to NASA's aviation research programs. Only in the aviation trade press does one find articles about climate change and aviation. These few articles tend to focus on reports about the meetings or activities of ICAO and the actions being taken or proposed by European governments (national and local) regarding charges related to aircraft emissions. The low profile of aviation in the climate debate is perhaps its most glaring feature. While there is some comfort to be taken from this low profile in what may become an emotionally charged political debate, there are also risks. It is difficult for a low profile program to effectively compete for scarce research funds.

[65] Ibid.
[66] Ibid.

Economic Importance:

Aviation contributes significantly to our balance of trade and overall economy. In addition to its contribution to our economy, it has been important to our national defense and our technological prestige. Aviation is also an important source of employment. The table below shows the number of people directly employed in the aviation industry in the United States, including the operation of airlines and airports. The average employment for 1996 was over one and one-half million and the projected employment for the year 2006 is estimated to approach 2 million.

Employment in aircraft and parts manufacturing has shown significant cyclic swings. In 1998 the aircraft industry provided 523 thousand manufacturing jobs in the United States.[67] This represented 3.5% of all manufacturing jobs in the United States in that year. Employment by air carriers in the United States is more than double that of the aircraft and parts manufacturing.

Table 4
Aircraft Employment Statistics

Category	1996	Est. 2006
Aircraft and Parts (mfg)	459,500	512,500
Air Carriers	1,009,300	1,258,311
Airports	112,800	142,689
Total Employment	1,581,600	1,913,500

Source: the Bureau of Labor Statistics, Employed Persons by Detailed Industry.

In international trade, aircraft and aircraft parts is the United States largest single manufacturing category with a positive balance of trade. The value of U. S. exports of aircraft and aircraft parts ($6.1 billion for December of 1998), accounted for roughly one-eight of U. S. exports of manufactured goods in that month.[68]

Major manufacturers of aircraft and engines have all forecast passenger traffic growth through 2010 to increase at a rate of between 5 and 6 percent. ICAO has forecast a 5 percent growth in total passenger traffic and 6.5 percent growth in international passenger traffic. In addition to high growth expectations, U. S. scheduled airlines showed profits of $8.7 billion in 1997; by comparison the profits of the airlines of the rest of the world combined showed profits of $7.8 billion in the same year.[69] The recent profit levels and the continuing expectations for future growth have led to a significant increase in orders for new aircraft. This rosy outlook for the future has led the world's air carriers to order 1,309 Turbojet aircraft in 1997. This represents a financial commitment, based on order book value, of $78 billion. The comparable 1996 value was $65 billion. The backlog of unfilled orders stood at 3,062 aircraft at the end

[67] Bureau of Labor Statistics; National Employment, Hours and Earnings for Aircraft and Aircraft Parts.
[68] From the Export-Import Bank, Exports and Imports of Goods by Principal SITC Commodity Groupings—from Exhibit 15, monthly data for 1998 and 1997.
[69] Policies and Measures for Common Action, Tranche II, Annex I (FCCC). Aviation Statistics gathered by ICAO.

of 1997. In the past 10 years the number of aircraft (takeoff weight over 9 tonnes) has increased 60 percent to just under 17 thousand.[70] (The recent crises in Asian economies have had some dampening effect on this robust market, however, it is too early to know if this is a temporary or permanent cut back in orders.)

The United States has dominated the aviation industry worldwide through much of the post world war II period. This dominance is now being challenged by the European Consortium (Airbus), which in the last decade has garnered a growing share of the new aircraft market. It would appear that operating costs are becoming more important in the airline purchasers' decisions. Recent experience in Europe with the Double Annular-Combustor engine would suggest that the imposition of environmental charges by airports and nations is entering into that economic calculation regarding the purchase of aircraft.

X. Summary

Greenhouse gasses are the focus of international environmental discussions and agreements that climaxed with the 'Kyoto Protocol to the United Nations Framework Convention on Climate Change' in December 1997. Despite the attention being given these issues in international deliberations, the impact of the Protocol on international civilian aviation has not been determined. The provisions of the Kyoto Protocol specify that the measures governing emissions of greenhouse gasses for international civilian aviation will be addressed by the International Civil Aviation Organization (ICAO). (Domestic civil aviation will be handled as part of each nation's emissions budget.)

The 32nd ICAO Assembly asked that the council prepare a response to the Kyoto Protocol and the IPCC Report for consideration at its next regular meeting in late 2001. While ICAO has held meetings to discuss these issues, no provisions specific to the Protocol have been agreed to at this time. There is no certainty that a standard will be recommended at that time. Some observers feel that market based measures, such as emissions trading, could be recommended, along with technological and operational measures motivated by market forces.

Despite mounting scientific evidence, the lack of 'incontrovertible scientific proof', particularly regarding the impacts and timing of increased levels of greenhouse gasses, has significantly complicated the politics of global climate change. In the United States the interaction between the gaps in scientific knowledge and the increasingly polarized political arguments are clearly demonstrated in the debate over global climate change. Scientists in providing testimony before political forums have acknowledged that 'we don't know with any degree of precision how big the problem is… and we don't know how fast it is moving. Or, indeed, how it can be mitigated.' While such statements may be accurate scientifically, they do little to shed light on the political debate. More often these provide a political rationale for delay in making any decisions, particularly decisions that hold the potential for adverse economic impacts. Politicians conclude that given these uncertainties we should not rush into agreements that could cause harm to our economy. Instead they defer taking actions and call for more studies and more research.

The unsuccessful experience of the initial voluntary efforts to reduce global emissions made it clear that a legally binding pledge would be needed to successfully address the problem. This realization lead to the adoption of the Kyoto Protocol by some 160 nations in December of 1997. The protocol sought to provide an agreement that would begin the process of securing firm commitments from the community of nations toward the goal of reducing emissions of greenhouse gasses. Only participation by most of the larger nations of the world could achieve such a goal.

[70] Op cit, Export-Import Bank.

The Kyoto Protocol is the only vehicle before the community of nations for ratification. The importance of action by the United States to support global cooperation on climate change cannot be minimized. As the largest emitter of greenhouse gasses, the United States must play a leadership role, if such a cooperative effort is to succeed. Without U. S. participation it is unrealistic to believe that any global cooperative effort will move forward in the foreseeable future. However, for the United States the ratification step is burdened with scientific uncertainty and undermined with emotionally charged, increasingly partisan politics, this raises serious questions about U. S. ratification.

The political opposition to the Protocol is not without some justification. The exclusion of Developing Countries from the requirements imposed by the Protocol and the pressure by influential Developed Countries to adopt command and control measures have added to the political intensity and emotion. The vote on the Byrd Resolution clearly signals that there is overwhelming opposition to the Protocol as it stands. The signing of the Protocol by the President of the United States was basically a symbolic gesture; ratification by the Senate is required to make the agreement binding on the United States. Such a vote by the current congress seems unlikely as many of the important details related to the Protocol are still unresolved and are not scheduled to be taken up by the Kyoto Protocol's Convention of the Parties until the year 2000. For these and other reasons it appears that a vote on ratification will not occur before the presidential elections in the year 2000. Thus, the issue will be placed before a new President and a new Congress. It is likely that both will take a fresh look at the Protocol. These delays exacerbate the problem and raise questions as to the advisability of pressing to reach the targets set for the 2008 to 2012 time frame.

The implicit, if unstated, strategy of the United States to reach the Protocol targets is based on two approaches, namely, technology development and emissions trading. The more time available to accommodate this strategy, the more likely it is to be successful. Compressing the time frame to a few years is likely to guarantee failure. An obvious alternative would be to slip the target date by a few years; unfortunately this could open up the entire Protocol for amendment and could lead to still further delays.

The emissions trading mechanism, which is a key part of the implicit U. S. strategy, has not yet been put into effect because the ground rules for trading have not yet been promulgated. The Mack-Lieberman Early Action Bill has been introduced to provide some relief to those taking actions to reduce emissions before the Protocol is ratified, however, this bill has not yet been enacted into law. It is possible to make this provision retroactive; however, uncertainty surrounding the successful enactment of the bill and the uncertainty of ratifying the treaty are likely to discourage early investment to comply with the anticipated provisions of the Protocol.

How emissions trading provisions might apply to aviation is not clear. ICAO would be expected to play a key role in the development of any such emissions trading guidance applicable to international flights. Likewise, it is not clear how the Early Action Bill might apply to aviation for domestic or international flights. It is reasonable to assume that activities related to the manufacturing of aircraft and aircraft parts would be consistent with the treatment afforded other manufacturing industries.

The other piece of the strategy, namely, technology development, was initiated in October 1997 when a three-stage proposal on climate change was approved. The first stage of this proposal was designed to expedite the development and deployment of new, energy efficient technology. This included $3.6 billion for tax incentives for deploying the new technologies and $2.7 billion for research and development to be spent over a five-year period. While a portion of the research funding in the first stage of the plan was designated for transportation, none of that funding is available for aviation technologies.

Aviation is beginning to take on the appearance of a stepchild in the climate change deliberations. ICAO, the organization designated to develop the approaches for emissions reductions for aviation is being

pressured by independent action of local and national governments. Emissions charges for aircraft are beginning to appear at some European airports. At this time such charges are directed at NOx emissions that impact local air quality. The prospect of additional charges or taxes by other governmental entities appears likely to address the emission of greenhouse gasses.

ICAO's normal mode of operation, that is, the development and issuance of performance standards for aircraft, is somewhat out of step with the concept of national targets explicit in the Protocol. It is not clear how country targets would be applied to international aviation, nor is it clear how these would be implemented. The use of performance standards for aircraft is well established in the aviation industry and has effectively operated for over 50 years. It is reasonable to expect that ICAO would eventually pursue emissions standards as the method of choice for addressing greenhouse gasses. If and when such standards for fuel efficiency might be agreed upon is highly speculative. Furthermore, how these two different approaches, the performance standards for aircraft and the national emissions targets, will be reconciled, or if they need to be reconciled, is not apparent at this time.

The prospects of new environmental charges enacted by governmental entities in Europe raises an important issue for the U. S. aviation industry. These charges if based on emissions levels could impact the purchasing criteria considered by airlines when selecting new aircraft. It could also spur the development of new, lower emitting technologies, especially in Europe where these charges are likely to have the greatest impact. American engine manufacturers could see a portion of their market threatened by the emergence of lower emitting models with lower operating costs.

Based on current information, it appears that government funding of research programs geared toward reducing aircraft emissions is being reduced and some programs are being terminated. The cut backs in these programs will make it more difficult for American aircraft industries to respond to stricter emissions standards. Government aviation research has served as the foundation for many of the newer technologies that have advanced aviation performance in reducing emissions and noise which are the two primary environmental problems facing a growing aviation industry. Major environmental improvements in aircraft performance will be dependent on these basic research programs. As in any complex research program, long lead times are required before any implementation effort is undertaken. This is particularly true if major decisions are made in regard to changing from today's fuels.

How important will emissions be to the future of commercial aviation? Will emissions become an important discriminator in purchasing decisions for new aircraft (all other factors being equal)? Will emissions charges by local and national governments become more prevalent? Will they eventually spread to the United States making aviation technologies that reduce emissions and improve efficiency a top priority in both domestic and international competition? Will the aviation industry in the United States stay competitive by developing more efficient aircraft in a timely manner?

It is impossible to answer these questions from today's vantagepoint. One thing is clear; emissions of greenhouse gasses are viewed by much of the world as an increasingly important problem. It is reasonable to assume that aviation emissions will be part of that concern.

Appendix A

United States Global Climate Research Program

Of the total USGCRP FY99 budget request, 59% supports Space-Based Observation Programs while 41% supports Scientific Research. The FY99 request for $767 million for Scientific Research is a 3% increase above the FY98 budget level. The $1.097 billion request for Space- Based Observation Programs is a 2.3% reduction from the FY98 budget level.

(Dollars in Millions)

Agency[a]	**FY97**	**FY98**	**FY99 Research Request**
Department of Agriculture (USDA)	57	58	59
Department of Commerce (DOC/NOAA, DOC/NIST)	62	62	71
Department of Energy (DOE)	109	109	113
Department of the Interior (DOI)	29	29	29
Environmental Protection Agency (EPA)	14	15	21
Department of Health and Human Services (HHS)	4	4	5
National Aeronautics and Space Administration (NASA)	252	275	275
National Science Foundation (NSF)	166	167	187
Other	8	7	7
Scientific Research Subtotal	701	725	767
Space-Based Observation Programs:			
National Aeronautics and Space Administration (NASA)[b]	$ 1117	1092	1097
U.S. Global Change Research Program Total	$ 1818	1867[b]	1864

(a) The Department of Defense (DOD) sponsors research with applications to national security needs, but is also relevant to stated goals of the USGCRP. The DOD budget in FY97-FY99 for defense-related research that contributes to USGCRP activities follows: FY97--$10.7M ($4.9M above request); FY98--$6.5M ($0.8M above request); and FY99-- $6.7M. The Department of Transportation supports assessment efforts in the transportation sector that are relevant to the goals of the USGCRP.

(b) The FY98 USGCRP total includes $50M in the NASA budget to be transferred to the International Space Station, if necessary.